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16. ABSTRACT

An improved saturation apparatus for continuously generating large volumes of water solutions of hydrophobic compounds for conducting aquatic bioassays is described. Closed 19 L stainless steel soda carbonation vessels replace the open glass vessels commonly used. The apparatus has been used successfully with liquid, semi-liquid and solid compounds and has delivered up to 200 ml/min of toxicant ladened water to a test system. The modular design of this saturator makes the flow capacity almost infinite by simply connecting another vessel in line.

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Saturator System for Generating Toxic Water Solutions for Aquatic Bioassays

Flow-through toxicity tests are becoming more commonplace as environmental awareness increases the need for toxicity data on a variety of chemicals. Chemicals are being tested, or need to be tested, which have low solubility in water but which are soluble enough to have undesirable effects on aquatic organisms. Researchers use the following methods to obtain toxicity data on compounds with low solubility in water: premixing large volumes of water and toxicant, adding toxicant to a carrier solvent and injecting the solution into water (Schimmel et al. 1974; DeFoe 1975), or using saturating devices (Veith and Comstock 1975; Chadwick and Kiigemagi 1968; Gingerich et al. 1979). Use of a saturation device, such as the one described by Veith and Comstock (1975), is desirable because neither large reservoirs of toxicant solution nor additional solvents are required. Their device, however, has definite flow limitations and is complicated to build, operate, and maintain. The objective of the present study was to develop a simplified saturation device with an almost infinite flow capacity.

Soda carbonation cans of the type used in automatic vending machines were employed. These 19-L (5-gal) vessels of stainless steel construction have a large port at the top which allows easy access for cleaning and modification (Fig. 1). The vessel has quick-connect couplers (labeled "in" and "out") for attachment of tubes from a metering pump to the diluter system or between vessels. The out coupling of each vessel has a stainless steel tube running to within a few millimeters of the bottom of the vessel. We calibrated a metering pump, controlled by an adjustable timer, to deliver a desired amount of diluent water into the full saturator can (or cans) during each diluter cycle. When diluent water was added to the saturator an equal volume of saturated solution was forced into the exposure apparatus.

Liquids with higher specific gravity than water were poured into the vessel to a depth of 2–5 cm on the bottom and stirred with a magnetic stirrer slowly enough so that the compound was not emulsified or suspended in the water column. The metering pump was connected to the out coupling on the vessel for these compounds; by this means diluent water could be added to the bottom of the vessel containing the compound and saturated liquid removed near the top of the vessel.

This saturator system functioned equally well for liquids with a specific gravity lower than water. For compounds that floated on the water in the vessel, the pump was connected to the in coupling of the saturator cans; the diluent water could thus be pumped into the top of the can containing the compound and the saturated liquid forced out the bottom. To promote mixing, magnetic stirrers were also used with liquids that floated.

For solid toxicants, a filter (composed of a drilled neoprene stopper and a 30-cm length of 20-mm glass tubing) was installed on the in coupling of the vessel, as shown in Fig. 1. Glass wool was placed in the glass tubing to prevent undissolved compound from being pumped out. This method worked equally well whether the solid compounds sank to the bottom or floated to the top of the water. Solids were stirred rapidly with a magnetic stirrer which made a suspension in the saturator, thus increasing surface area contact with the water.

To test kelthane, a tar-like semiliquid, we first

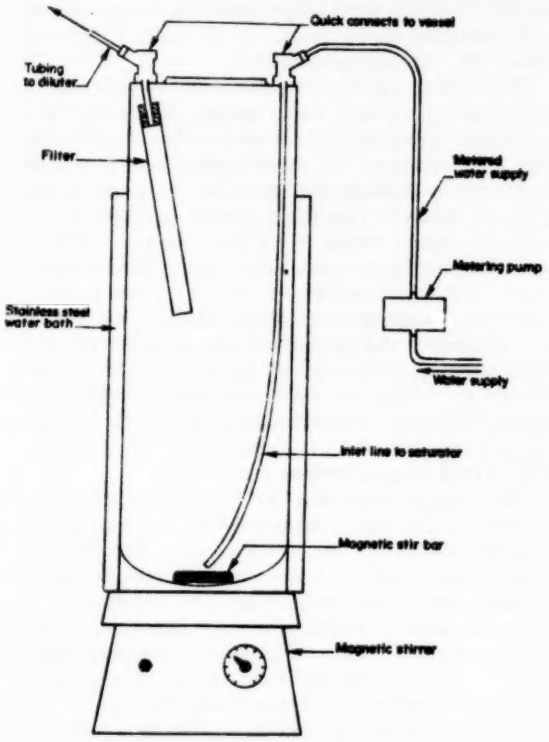

Fig. 1. Cut-away view of the saturator apparatus (carbonation can), showing the water jacket, the metering pump, and the magnetic stirrer and stir bar.

diluted it with acetone to the consistency of heavy paint and applied it with a natural bristle brush to a 10-mesh stainless steel screen that had been formed into a column 10 cm in diameter and 50 cm high. The acetone was allowed to evaporate and the screen column was then placed in the saturation vessel, which was immediately filled with water.

Pesticides with a consistency like honey, such as pydrin and permethrin, were coated on the sides of the vessel. About 20 g of compound were diluted with acetone to the viscosity of water and placed in the vessel, which was tipped to the horizontal position on a steam table. The vessel was then rotated on its horizontal axis until the acetone was completely evaporated. This procedure covered the sides of the vessel with droplets and effectively increased the surface area in contact with the water. The vessel was immediately filled with water to prevent the compound from sagging to the bottom.

The amount of compound added to the vessel varied. If the solubility was low and the toxicity was high, less compound was needed to achieve a lethal concentration. When the compound was fairly soluble, but toxicity was low, larger amounts of compound were added so the toxicant would not be exhausted before the test was completed.

To achieve higher concentrations of toxicant in water the vessels were either heated, or another 19-L vessel was connected. We found that the solubility and rate of dissolution of some compounds could be increased by heating the water in the water jacket (Fig. 1). When the system was heated, the temperature was maintained within ± 1 Celsius degree, and care was taken neither to exceed the degradation temperature of the compound nor to exceed the compound's solubility in water at the test temperature. If saturation was exceeded, the compound would condense and form droplets of compound in the chamber of the diluter to which the supersaturated solution was added. However, better toxicant concentration uniformity was achieved by adding more vessels in line; heat should be used only as a last resort.

The "soda can saturator" has been used successfully to solubilize, in water, chemicals with varying degrees of hydrophobicity. The coefficients of variation of water samples taken from the high concentration exposure tanks and analyzed daily during 96-h acute exposures were as follows: tetrachloroethylene, 15.3%; 1,1',2,2'-tetrachloroethane, 25.3%; pentachloroethane, 5.7%; 1,1',2-trichloroethane, 11.8%; hexachlorobutadiene, 6.1%; 1,1',2-trichloroethylene, 2.3%; 1,2-dichloropropane, 22.1%; 1,2-dichloroethane, 33.2%; hexachloroethane, 26.2%; 1,3-dichloropropane, 2.8%; kelthane, 13.5%; dursban, 8.7%; disulfoton, 17.8%; pydrin, 22.1%; and permethrin, 23.4%. These coefficients of variation also include the normal variation of the dosing apparatus and the variation in the analytical methods used for measuring the compounds. Thus, they underestimate the precision achievable with this saturator. The chemicals tested have been in solid, semiliquid, and liquid phases. Although the saturator has not been tested with chemicals in the gaseous phase it should work with them also, since its original purpose was to dissolve carbon dioxide in soda pop.

Because the system is completely closed, it works well with volatile compounds. This has two distinct advantages: the compound is not lost to the atmosphere, and the work space is not contaminated. These advantages are especially important when heat is applied to increase solubility, since volatility is then also increased.

The use of a metering pump to displace toxicant-laden water with fresh water simplifies the water replacement system. The pump and the water replacement systems can be reused since they are on the influent side of the system and, thus, are not contaminated.

The design and simplicity of the system makes cleaning easy—an important consideration in short-term testing. Since large numbers of chemicals are often used in short periods, frequent and thorough cleaning is necessary to prevent toxicant carry-over from test to test. The stainless steel construction enables the use of solvents, acids, or bases in cleaning, cuts down on breakage, and insures safe handling.

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